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TILLEYITE, A NEW MINERAL FROM THE CONTACT ZONE AT CRESTMORE, CALIFORNIA

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INTRODUCTION

The contact metamorphic zone at Crestmore, California, where granodiorite and quartz monzonite have invaded limestone, has already yielded seven new mineral species, and in addition some fifty-three other previously known species. An examination of blocks of the material from the Wet Weather quarry, collected by the senior author during 1932, has revealed the presence of a new lime silicate-carbonate mineral, with distinctive optical and chemical properties. For the new mineral the name tilleyite is proposed in honor of Professor C. E. Tilley of Cambridge University, England, in recognition of the contributions he has made to the study of metamorphism.

ASSOCIATED MINERALS

A summary of the minerals already recorded from Crestmore has been given in a paper by A. F. Rogers (1929). It will therefore suffice here to mention only those minerals which have been found in intimate association with the tilleyite. The rock in which the new mineral was discovered is a hard green material, the color being imparted by the presence of abundant merwinite. The grain size, though not fine, is such that individual grains cannot be distinguished with the naked eye. Brown streaks of vesuvianite traverse the rock, and with these a light colored grossularite is associated. Tilleyite appears to be most abundant in white patches, where it is associated with wollastonite. Spurrite is present in limited amounts, as well as a mineral which corresponds in all its optical properties with gehlenite, but shows "microcline" twinning in basal sections. This assemblage appears to represent the more intensely metamorphosed part of the contact zone, and calcite is present in insignificant amount only. Veinlets of thaumasite traverse the rock, and there is also a white powdery alteration product coating the surface of the blocks, part of this is hydromagnesite.

An examination of the collection of material from Crestmore in the Mineralogical Museum of Harvard University showed that tilleyite is present in a number of specimens. In these, the mineral assemblage is similar to that described above. On the other hand, tilleyite was not detected in specimens which contained large amounts of recrystallised calcite, as do those in which wilkeite, brucite and diopside are important constituents.

Optical Properties

Tilleyite is biaxial, with refractive indices, determined by the immersion method, as follows: $\alpha=1.617$, $\beta=1.635$, $\gamma=1.652$; all ±.003. Inspection of the interference figures exhibited made it evident that the optic axial angle is large, approaching 90°. This was confirmed by means of the Fedorov stage. An optical sign cannot therefore be assigned with complete certainty, but the mineral is probably positive. If this is so, the dispersion of the optic axes, which is fairly conspicuous, is $r<v$ (perceptible). The optical orientation was obtained by the use of the Fedorov stage. Within the limits of experimental error, the β-index direction was found to lie in the plane of the perfect cleavage. The α- and γ-directions are

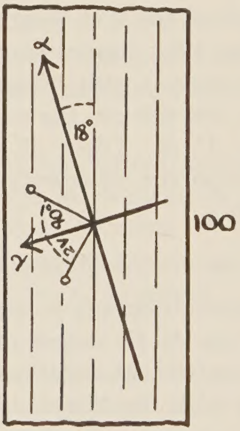

Fig. 1. Optical orientation of tilleyite.

both inclined to this plane. It is therefore suggested that the mineral is monoclinic; that the *b*-crystal axis be taken as parallel to the β index direction, and that the plane of the cleavage be assumed to be parallel to (100). The *c*-crystal axis then also lies in the cleavage plane, and the angle $X \wedge c$ is 18°. The accompanying diagram summarises the proposed orientation.

Twinning has not been detected in tilleyite, but in addition to the perfect cleavage discussed above there is another ill defined cleavage which was detected in only one thin section. This makes an angle of about 42° with the perfect cleavage, and is inclined at 18° to the proposed *b*-crystal axis.

PHYSICAL PROPERTIES

In powder, tilleyite is white without lustre. There is one perfect cleavage, and in addition one ill-defined cleavage. The presence of the perfect cleavage causes abundant cleavage fragments to appear in the powder. Calculation of the specific gravity by Gladstone and Dale's law gave as a result Gr. = 2.90; while determination by means of the quartz pycnometer showed that the density is 2.838. The hardness has not been determined owing to lack of sufficiently large grains.

CHEMICAL PROPERTIES

A sample was separated for analysis from the original rock by means of heavy liquids, bromoform-methylene iodide mixtures being used. It became apparent in the process of separation that the amount of tilleyite in the rock was small, being of the order of 0.5 to 1.0%. The impurities remaining in the analyzed powder were estimated as follows: wollastonite 2%, spurrite 1.5%. Preliminary tests showed that the mineral effervesces vigorously with cold dilute hydrochloric acid, and gelatinizes. The results of an analysis are given below:

SiO_2	24.09
Al_2O_3	0.61
Fe_2O_3	0.12
MgO	0.43
CaO	57.75
H_2O	1.09
CO_2	15.82
	99.91

Analyst, F. A. GONYER

The analysis shows the mineral to be composed essentially of lime, silica and carbon dioxide. Correction for the estimated impurities, and recalculation of the principal constituents to 100% gave the results in column I below:

	I	II	III	IV
SiO_2	24.00	0.399	22.1	0.376
CaO	59.60	1.063	61.8	1.180
CO_2	16.40	0.372	16.1	0.376

The molecular ratios (column II) suggest an empirical formula $3CaO \cdot SiO_2 \cdot CO_2$; the theoretical percentage weights are given in column III, and the molecular proportions of these in column IV. Examination of other possible formulae showed that only a very complex one would fit the analysis better than the one assigned, and we have decided, pending the availability of purer material for analytical purposes, to present the formula in its simple form.

Thin sections cut from the blocks in which the mineral was first found show that while it is homogeneous, some grains show borders having a lower birefringence than the rest of the grain. The zoned texture does not appear to be due to alteration, but more probably represents variation in composition. It was not found possible to take any account of this effect, but it is suggested that the slight divergence of the analysis from the theoretical composition proposed may perhaps be due in part to the presence of these borders.

The Scawtite-Tilleyite-Spurrite Group

Three naturally occurring minerals in which carbon dioxide has combined with calcium silicate are known. These are spurrite, originally described by F. E. Wright (1908), scawtite, described by C. E. Tilley (1929B) and tilleyite. Tilleyite and spurrite may be expressed in structural formulae showing a molecule of calcium carbonate combining with one and two molecules of calcium-olivine, respectively. Scawtite is not capable of being expressed in a simple structural formula of this type.

The table which follows summarizes some of the properties of the group. Those of larnite, the calcium-olivine first discovered in the Scawt Hill contact-zone by C. E. Tilley (1929A) have also been inserted for reference:

	SCAWTITE	TILLEYITE	SPURRITE	LARNITE
SiO_2	34.2	24.1	26.9	31.0
CaO	46.4	59.5	62.3	64.9
CO_2	18.0	16.4	9.7	0.0
Formulae:	$2CaCO_3 \cdot Ca_2Si_3O_8$	$CaCO_3 \cdot Ca_2SiO_4$	$CaCO_3 \cdot 2Ca_2SiO_4$	Ca_2SiO_4
$\alpha=$	1.597	1.617	1.640	1.707
$\beta=$	1.606	1.635	1.674	1.715
$\gamma=$	1.621	1.652	1.679	1.730
Birefringence=	0.024	0.035	0.039	0.023
Sp. Gr.=	2.77	2.838	3.014	

There is thus a gradation in properties within the group. Increasing refractive index may be correlated with increasing lime percentage, and decreasing carbon dioxide. Similarly, the specific gravity increases with the decrease of carbon dioxide.

REFERENCES

Tilley, C. E., 1929A. On larnite and its associated minerals from the limestone contact zone of Scawt Hill, Co. Antrim: *Min. Mag.*, **XXII,** pp. 77–86.

Tilley, C. E., 1929B. Scawtite, a new mineral from Scawt Hill: *Min. Mag.*, **XXII,** pp. 222–224.

Rogers, A. F., 1929. Periclase from Crestmore, with a list of minerals from this locality: *Amer. Mineral.*, **XIV,** pp. 462–469.

Wright, F. E., 1908. On three contact minerals from Velardena, Durango, Mexico: *Amer. Jour. Sci.*, **XXVI,** 4th Ser., pp. 545–554.

A NOTE ON THE TEXTURE OF THE CRESTMORE CONTACT ROCKS

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The original purpose of the present note was to record the microscopic textural relations of the new mineral tilleyite, described in the preceding paper, with its associated minerals. The scanty attention which has been accorded to the textures of the Crestmore contact zone, in spite of its extensive literature, appeared to justify a somewhat more general treatment.

A. S. Eakle (1917) has attributed the metamorphism to the influences of three intrusives, a granodiorite, a quartz monzonite porphyry, and a series of pegmatite dikes. The earliest result of the invasion of the limestone may reasonably be supposed to have been the complete recrystallization of the rock. The grain of the resulting marble is coarse, and on Sky Blue Hill the grain size of the blue recrystallized calcite often exceeds 20 mm. In this rock there appear the minerals whose presence bears witness to the activity of solutions emanating from the cooling igneous rocks. As long as there remains any considerable amount of calcite, the new minerals appear as rounded or idiomorphic metacrysts. Grossularite, diopside, wollastonite, and vesuvianite are among the minerals which have developed good crystal outlines. The granular texture here is the one usually found in metamorphosed limestones.

Graphic Textures

In more intensely altered material, however, in which almost all the calcite has been replaced, the rock no longer has a simple granular texture, but shows a series of intergrowths which considered as geometrical patterns are identical with the micrographic texture familiarly seen in metals, metallic ores and igneous rocks. Such textures have not previously been described from lime-silicate rocks. In the Crestmore material, the following pairs of minerals have been observed in these relations:

Wollastonite—tilleyite
Wollastonite—gehlenite
Wollastonite—vesuvianite
Merwinite—grossularite

The origin of the graphic texture has been a much debated subject during the past decade, and it seems evident that no universally applicable mode of origin can be assigned to it. In the present case, an outstanding fact is that while one member is optically continuous over considerable areas, the other is generally not. Moreover, features such as twin-lamellae are sometimes clearly continuous in the dissected optically continuous individuals (see Fig. 1). This suggests that the optically continuous member was once physically continuous, and support for this view is found in the existence of all stages from complete individuals to highly intricate intergrowths, the stages corresponding to increasing completeness of replacement. The particular pattern shown is due to replacement having been controlled by the cleavage directions of the wollastonite and merwinite, these being the first-formed minerals. Wollastonite with its three cleavages is especially well adapted to respond in this way to replacement. Confirmation of the suggested mode of origin of the micrographic textures is provided by the clear evidence that each of the second named minerals also attacks and replaces wollastonite and merwinite without producing intergrowths. Tilleyite appears to have been a later mineral than wollastonite, merwinite, spurrite and gehlenite, for it appears along the grain boundaries between these minerals. Grossularite is later than all these minerals and cuts across all impartially.

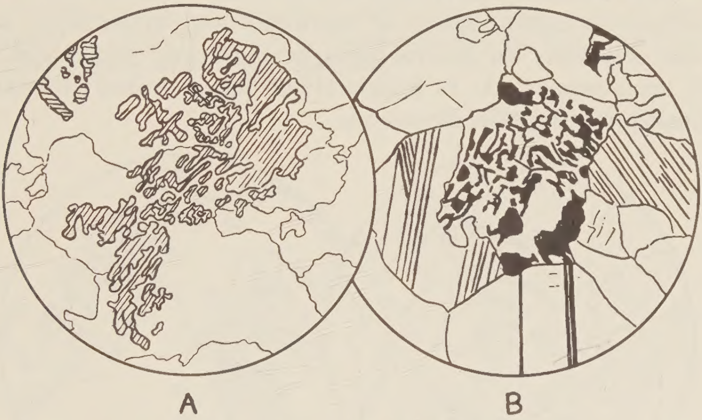

Fig. 1. Camera lucida drawings.

A, Merwinite (showing fine twinning), partly replaced by grossularite. The merwinite apparently remains from a single individual grain.

B, Tilleyite (black) replacing wollastonite along cleavage directions. Sketch also shows twinned merwinite grains.

Inclusions

Less readily interpreted are the orientated inclusions of merwinite which occur in wollastonite. These are generally parallel to the {001} cleavage, though some also appear parallel to the {100} cleavage. The former cleavage is apparently poorly developed in spite of the great number of inclusions which follow its direction. The inclusions have a sharp rectangular form (Fig. 2A) and in view of their parallel orientation cannot be regarded as replacement residuals. The fact that their outline is clearly controlled not by the crystallography of the merwinite but by that of the wollastonite is an argument against an origin as metacrysts. The only remaining possibility is, therefore, that these represent simultaneous crystallization of merwinite and wollastonite; and to this possibility the general relationship of these minerals in the rock lends support. A. F. Rogers (1929) has described orientated inclusions of magnetite in periclase.

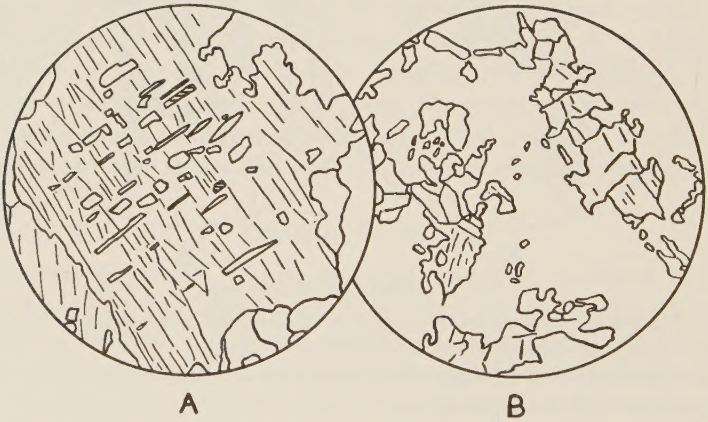

Fig. 2. Camera lucida drawings.

A, Inclusions of merwinite in wollastonite, orientated parallel to the {001} cleavage.

B, Irregular remnants of wollastonite in vesuvianite.

Sequence

While it is not possible, owing to the scattered nature of the minerals in the rock, to present a complete succession of minerals, the following sequence, based upon observed replacement relations, may be of interest:

1. Recrystallization of limestone
2. Wollastonite, merwinite, spurrite, monticellite
3. Gehlenite
4. Tilleyite
5. Garnet, vesuvianite
6. Thaumasite, in cross cutting veinlets

Several specimens also showed that diopside is replaced by garnet and vesuvianite. The sequence of minerals is held to reflect the sequence of changes in composition of the solutions. The relatively late accession of alumina-rich minerals is noteworthy.

REFERENCES

Eakle, A. S., 1917. Minerals associated with the crystalline limestone at Crestmore, Riverside County, California: *Univ. California Geol. Bull.*, **x**, pp. 327–360.

Rogers, A. F., 1929. Periclase from Crestmore, with a list of minerals from this locality: *Amer. Mineral.*, **xiv**, pp. 462–469.

AN OCCURRENCE OF ISO-ORTHOCLASE IN VIRGINIA

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The iso-orthoclase which will be described in the present note was found in a granitic gneiss in northern Virginia. This gneiss forms the highest crests of the Blue Ridge east of Luray, Va. Specimens were collected along a newly constructed highway running through the southern part of an area topographically mapped as Sheet 4 of the Shenandoah National Park. The gneiss is a typical injection gneiss with parallel oriented crystalloblasts of potash feldspar in a fairly coarse-grained matrix of quartz, plagioclase, and biotite.

The potash feldspar is always perthitic and may, according to common practice, be classified in part as orthoclase, and in part as microcline, the difference being that microcline shows an inclined extinction, whereas orthoclase, being a monoclinic mineral, is supposed to show parallel extinction in the zone normal to (010). The indices of refraction of this potash feldspar seem to be fairly constant and are about: $\gamma = 1.528$, $\alpha = 1.523$.

A closer inspection of the feldspars (with the Fedorov stage) brought out the interesting fact that the value of the optic axial angle varied conspicuously in various grains, and a total range from $(-)\ 2V = 10°$ to $(+)\ 2V = 86°$ was observed. Now it is well known that orthoclases with small axial angles occur (although as far as the present author knows they have not before been encountered in highly metamorphic gneisses), but the existence of an optically positive orthoclase or an iso-orthoclase seems worthy of special notice.

Only once before has an optically positive orthoclase been observed. It has been described by Duparc[1] and by him given the name, "iso-orthoclase." It is said to occur in granites and porphyritic granites from Troitsk (Ural), but the description given is not very definite. Neither indices of refraction nor optical orientation were measured by Duparc. He only stated that the orthoclase was optically positive with an axial angle that in all cases was relatively small and probably slightly variable.

[1] Duparc, L., Sur une nouvelle variété d'orthose. *Compt. rend.*, **138**, 714, 1904.

(Excerpt: ". . . il est en tout cas relativement petit et probablement légèrement variable.")

It should therefore be of some interest to record the optical constants of the Virginia iso-orthoclase.

A stereographic projection normal to the *c*-axis of the iso-orthoclase is given (Fig. 1). The direction γ is normal to (010) or nearly so, the mineral is consequently an orthoclase rather than a microcline; $a:\alpha=0°$; (+) $2V=86°$; indices of refraction as given above.

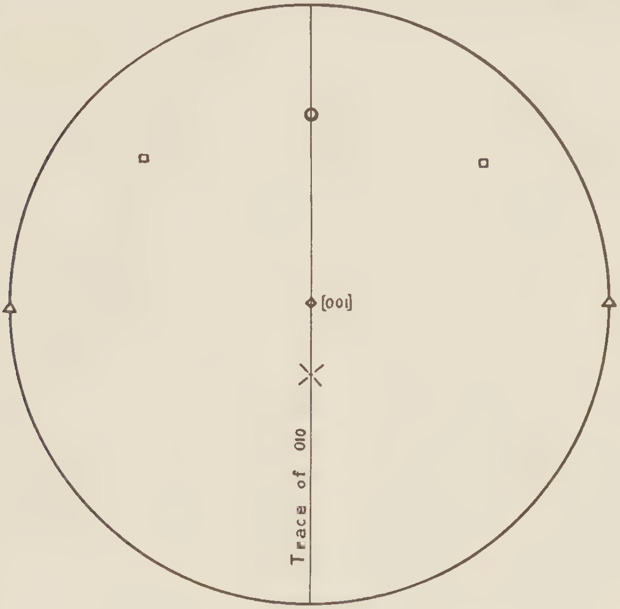

FIG. 1.

Stereographic projection normal to the *c*-axis of the Virginia iso-orthoclase. The pole of (001) and the direction β coincide and are marked with a cross, ×. ○ $=\alpha$, △ $=\gamma$, □ = optic axes.

According to these data the existence of an optically positive orthoclase must be accepted, and thus far the conclusions of Duparc are verified. But, whereas the Ural iso-orthoclase has a "relatively small" axial angle, the Virginia iso-orthoclase has a large axial angle. In view of the great susceptibility of variation in the optical angle of orthoclase it is in itself not so surprising that sometimes the angle may equal and even pass 90°, and thereby become positive, although the reason for this is just as little understood as the reason for the small, negative axial angles so frequently encountered in orthoclases associated with extrusive rocks.

AMMONIOBORITE, A NEW MINERAL*

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SUMMARY

Ammonioborite, a new mineral, is a hydrous borate of ammonium, from Larderello, Italy. In chemical composition it is identical or very similar to the known borate, larderellite, but its optical properties are different. The exact formula of both minerals is uncertain; they seem to represent dimorphous forms of $(NH_4)_2O \cdot 5B_2O_3 \cdot 5H_2O$.

Optically both minerals are positive, $2V$ about 60°, with a high birefringence of 0.07. The refractive indices of ammonioborite are: $\alpha = 1.470$, $\beta = 1.487$, $\gamma = 1.540$; of larderellite, $\alpha = 1.493$, $\beta = 1.509$, $\gamma = 1.561$; and of the artificial salt $(NH_4)_2O \cdot 5B_2O_3 \cdot 8H_2O$, $\alpha = 1.426$, $\beta = 1.429$, $\gamma = 1.486$.

INTRODUCTION

The specimen of ammonioborite first studied, was purchased by the U. S. National Museum, from Willy Hirsch, a mineral dealer in Germany, under the label "bechilite." The writer, in his studies of the natural borates, extending over many years, has never been able to find a specimen of true bechilite.

On seeing the specimen in the National Museum, labeled bechilite, the writer made several qualitative tests to see if it really was bechilite, but as it dissolved readily in hot water, the mineral evidently was not a calcium borate. Further tests showed the absence of calcium and the presence of only boric acid, ammonia, and water. Determination of the optical properties showed that it was different from larderellite and consequently a new ammonium borate, which is here named ammonioborite. The late Dr. G. P. Merrill was kind enough to permit the sacrifice of about half of the small specimen, which weighed only two grams, in order to determine its properties and composition.

Ammonioborite is very similar in composition to larderellite but sufficiently different in properties to show their separate distinctness. The interpretation of the analyses of ammonioborite presented considerable difficulty, as the new mineral was mixed with variable quantities of sassolite. As the available material was very limited in quantity, the analytical results obtained and here presented, are not as satisfactory as could be desired. Were it not for the difference in the refractive indices and the absence of the characteristic rhombic shape of the crystals of larderellite, the new mineral could not have been differentiated therefrom.

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Chemical analyses indicate that the new mineral has the formula $(NH_4)_2O \cdot 5B_2O_3 \cdot 5H_2O$. This is also the formula now accepted for larderellite,[1] the old formula $(NH_4)_2 O \cdot 4B_2O_3 \cdot 4H_2O$, based on a single analysis, being discredited.

In a more recent paper by d'Achiardi[2] the two new analyses of larderellite given support the formula $(NH_4)_2O \cdot 5B_2O_3 \cdot 5H_2O$. As however no quantitative optical data are given for any of the material analyzed by him it remains uncertain whether his material was larderellite or ammonioborite. The formula of larderellite must still be considered as somewhat uncertain.

The values of the indices of refraction of the two minerals are sufficiently different to show that there are two ammonium borates occurring at Larderello, Italy. X-ray patterns confirm this conclusion. If they have the same composition, they are dimorphous. All of the samples of both minerals, available for study, contain considerable sassolite. Larderellite apparently forms only very sharp straight-edged rhombic-shaped crystals; ammonioborite forms very fine-grained granular masses as well as crystals which rarely are bounded by straight lines, the edges usually being considerably rounded.

Description of Ammonioborite

The specimen first studied is a compact mass of white material, showing in the difference of luster, the presence of two minerals. The ammonioborite is granular, white, and lustrous, while the associated sassolite is duller, and more powdery. In general appearance and color, luster, and hardness, the new mineral closely resembles larderellite and can not be told therefrom by visual inspection.

Much of the ammonioborite is an aggregate of irregularly bounded masses, compacted together and intergrown with sassolite. Individual crystals also occur whose edges are characteristically somewhat rounded in striking contrast to the straight-edged rhombic-shaped crystals of larderellite. The outlines of some of the more typical crystals of ammonioborite are shown in Fig. 1, A.

[1] d'Achiardi, G., Boric acid and borates of the boron solfotaras in Tuscany: *Annali d. Univ. Toscane,* (Sci. nat.), Pisa, vol. **23**, pp. 1–34, 1901, and Larderellite from the solfotaras of Tuscany: *Rendi R. Acad. Lincei,* Rome, vol. **9**, fasc. 11, pp. 342–345, 1900. Abstr. in *Zeitsch. f. Krystall.*, vol. **35**, pp. 519–521, 1902.

[2] d'Achiardi, Giovanni, Nuovi dati e ricerche sulla larderellite: *Periodico di Mineralogia,* vol. **1**, No. 3, pp. 3–8, 1930.

These outlines are distinctly different from those shown by larderellite, the most typical of which are shown in B. A more complete presentation of the outlines of the various modifications of crystals of larderellite is given by d'Achiardi.[3] The different shapes illustrated by him are due to the development of the basal cleavage, as shown by Larsen.[4]

Much of the ammonioborite is very fine grained. Many of the grains are irregular in shape and are composed of a mosaic of minute individuals, heterogeneously aggregated, so that the grains show no extinction but retain the bright interference colors in all positions. A few of the mosaic-like grains approximate in outline to forms of larderellite, suggesting that if the two minerals have a different chemical composition, the ammonioborite is pseudomorphous after larderellite. If the two minerals have the same composition, and a paramorphic change has taken place, the direction of change is likewise that of ammonioborite after larderellite.

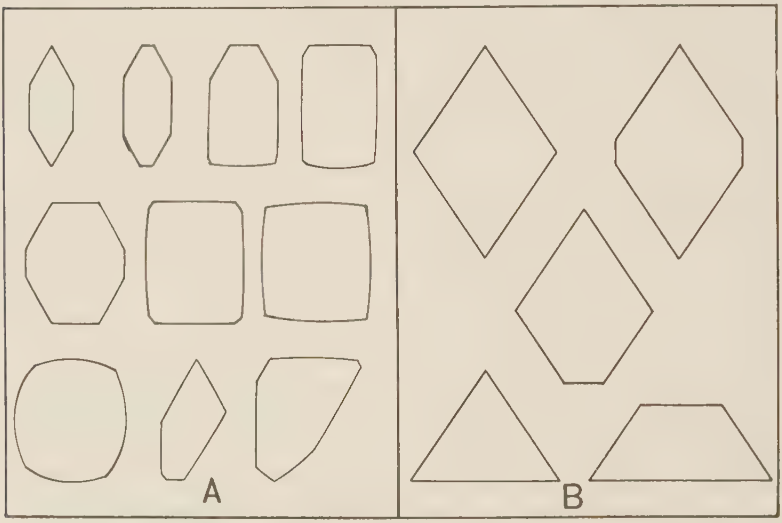

Fig. 1. A, Outlines of individual crystals of ammonioborite;
B, Outlines of crystals of larderellite.

The most perfect crystals of ammonioborite were observed on one corner of a specimen in the U. S. National Museum (U. S. Nat. Mus. Catalog No. 93756), labelled larderellite. These crystals are similar in shape and size to those observed on the specimen of supposed "bechilite" but in some of them the edges are much straighter though characteristically most of the edges are more or less rounded.

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[3] d'Achiardi, G., Boric acid and borates of the boron solfotaras in Tuscany: *Annali d. Univ. Toscane,* (Sci. nat.) Pisa, vol. **23**, pp. 12–13, 1901.

[4] Larsen, E. S., The microscopic determination of the nonopaque minerals: *U. S. Geol. Survey, Bull.* No. **679**, p. 98, 1921.

The best measurements gave an average value of about 57° for the upper acute angle of the crystals. This is not far from the angle of 68° measured for crystals of larderellite by d'Achiardi.

Another characteristic distinction between the two minerals is the absence in the better formed individual crystals of ammonioborite of a well developed cleavage, normal to the plates, which in larderellite often truncates the acute corners of the rhombs, as shown in Fig. 1, B. The crystals of ammonioborite are platy, many of them grouped together in parallel position, and can be observed on edge imbedded in the sassolite. The crystals reach an observed maximum length of about 0.08 millimeter, averaging from 0.015 to 0.03 millimeter, and are from a half to a third as wide.

Ammonioborite is either monoclinic or triclinic. Several of the crystals suggest triclinic, others seem more monoclinic in their symmetry.

The density of ammonioborite was not determined.

It was readily observed that when the coarsely crushed mixture of ammonioborite and sassolite was treated with cold water, part of the mixture readily dissolved, leaving a sandy residue of much less ready solubility. The sassolite readily dissolves in cold water, leaving most of the ammonioborite behind in a sandy powder, the sassolite having acted as a cement for the whole specimen.

Optical examination showed that the sandy residue of ammonioborite was not changed to a different salt by the action of the cold water. A portion of it remained undissolved for a considerable time. Comparative tests showed that for material of about the same grain size (diameter of particles about 0.1 m.m.), 0.2 gram of artificial sassolite (boric acid) dissolved completely in 75 cc. cold water in about 15 minutes and in less time if constantly stirred, whereas ammonioborite did not completely dissolve, under the same conditions in less than 2 hours, even if stirred. Advantage was taken of this difference in solubility to prepare a small sample of ammonioborite free from sassolite for analysis and for X-ray study.

OPTICAL PROPERTIES

The better developed crystals of ammonioborite show a small inclined extinction against their elongation. Measurements ranged from 7 to 13°, mostly closer to the lower figure. The direction of elongation corresponds closely to Z, the crystals becoming almost invisible in an immersion liquid of index 1.54. The mineral is positive and the obtuse bisectrix X, emerges from the large flat face of the crystals, which, if ammonioborite is monoclinic, would be the clinopinacoid $b\{010\}$ with the axial plane normal thereto. The axial angle $2V$ is medium, about 60° ±, dispersion, $r<v$.

The refractive indices of ammonioborite determined in the sample with admixed sassolite are given below under 1, and the indices determined on the same material washed free from sassolite under 2. These values are essentially identical with those of the unknown mineral from Larderello described twice by Larsen,[5] once on page 45, under Bechilite No. 2 (specimen from the American Museum of Natural History, New York), and again on page 50, under Boussingaultite No. 2 (collection of Col. Roebling, now in the U. S. National Museum). This last specimen was examined through the courtesy of Dr. W. F. Foshag and found to be an ammonium borate, mixed with sassolite, but free from magnesium and sulphate and therefore cannot be boussingaultite. The optical properties show that it is ammonioborite. The indices of refraction of these two minerals, as given by Larsen, are reproduced under 3 and 4.

Of the three specimens labeled larderellite in the U. S. National Museum, only one (U. S. Nat. Mus. Catalog No. 85174, described by Larsen[6]), is larderellite, the other two being ammonioborite. Of the latter two, one (U. S. Nat. Mus. Catalog No. 93756) is largely yellowish sassolite with small white masses of ammonioborite (indices given under 5 in Table 1), and the other (U. S. Nat. Mus. Catalog No. 94172) is a loose powder of ammonioborite (indices given under 6 in Table 1). Ammonioborite, therefore, seems to be a relatively common mineral at Larderello, Italy, and in fact may be more abundant there than larderellite.

The average of these six sets of determinations of indices of refraction of ammonioborite is given under 7 in Table 1.

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[5] Larsen, E. S., *loc. cit.*

[6] Larsen, E. S., *loc. cit.*, p. 98.

TABLE 1. OPTICAL PROPERTIES OF AMMONIOBORITE

	1	2	3	4	5	6	7
	Mixed with sassolite	Washed free from sassolite	Larsen, Bechilite No. 2	Larsen, Boussingaultite No. 2	U.S. Nat. Mus. 93756	U.S. Nat. Mus. 94172	Average
α	1.467	1.469	1.470	1.473	1.471	1.474	1.470
β	1.487	1.488	1.488	1.486	.....	.....	1.487
γ	1.541	1.539	1.542	1.539	1.539	1.541	1.540
$\gamma-\alpha$	.074	.070	.072	.066	.....	.....	.070
Sign	+	+	+	+	.....	.....	+
2V	Medium	.....	62° ± 5°	55° ± 5°	Medium	.....	60° ±
Dispersion	.....	r<v	Slight	.....	.....	.....	r<v

The refractive indices of larderellite have been measured by the writer and Dr. C. S. Ross has also redetermined them. The results are shown below in Table 2 and for comparison, the average values for ammonioborite are given in the last column.

TABLE 2. OPTICAL PROPERTIES OF LARDERELLITE

	Larsen	Schaller	Ross[c]	Average[d]	Ammonioborite
α	1.509[a]	1.493	1.493	1.493	1.470
β	1.52[b]	1.512	1.509	1.509	1.487
γ	1.561	1.561	1.561	1.561	1.540
$\gamma-\alpha$	.052	.068	.068	.068	.070
Sign	+	+	+	+	+
2V	60° ±	60° ±	58°	58°	60° ±
Dispersion	.....	.....	r<v	r<v	r<v
Orientation	$X=b$	$X=b$	$X=b$	$X=b$	.....
[e]	$Z\wedge c=24^\circ$	$Z\wedge c=$ small	$Z\wedge c=15^\circ$	$Z\wedge c=$ small	.....

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[a] Larsen's value for α is too high.

[b] Approximate. Given as 1.52 ± 0.01.

[c] Very carefully made. Error about ±0.001.

[d] The value of β determined by Ross is taken.

[e] As observed on the flat lying crystals, the extinction is parallel to the diagonals of the rhomb-shaped crystals.

Some of the optical properties of the two minerals are very similar, thus both are positive, the optic angle 2*V* is almost the same, and the birefringence (0.07) is practically identical.

On the other hand there are some marked differences, as the following tabulation shows.

Table 3. Differences in Optical Properties of Ammonioborite and of Larderellite

	Ammonioborite	Larderellite
Shape	Irregular, crystals with rounded outlines	Straight-edged rhombs
Cleavage	Not observed	Perfect {001}
Extinction on platy crystals	Inclined, 7°+	Parallel
Emerges on plates	X	Y
α	1.470	1.493
β	1.487	1.509
γ	1.540	1.561

The two minerals can readily be differentiated optically by immersing them in oils of known index. In an oil of index of 1.49–1.50, larderellite disappears when the shorter diagonal of the rhombs is parallel with the vertical cross-hair of the microscope, whereas ammonioborite stands out in relief in all positions, one direction of extinction being much lower and the other much higher, in index value, than the oil. In an oil with index of 1.56, larderellite disappears when the longer diagonal of the rhombs is parallel with the vertical cross-hair, whereas ammonioborite stands out clearly defined, all indices being lower than 1.56.

Chemical Composition

Qualitative tests showed the presence of only ammonia, boric acid, and water. The admixed sassolite (boric acid) presented difficulty in the analysis as at first no way was found to remove it. Finally, it was found that it could be dissolved in cold water. In this way a very small sample (0.09 gram) of pure ammonioborite was obtained, which was seen on microscopic examination to be free from sassolite. Sassolite can readily be recognized microscopically as it is nearly isotropic, 2*V* being only 7°, so that the plates normal to the acute bisectrix show a very low birefringence, with a nearly uniaxial figure. The birefringence of ammonioborite is high, yielding brilliant interference colors.

Attempts were made to prepare ammonioborite artifically so that the composition of this compound could be determined on ample material before the natural mineral was analyzed. All such attempts resulted in failure. Larderellite likewise has not been been made artificially. The well known compound $(NH_4)_2O \cdot 5B_2O_3 \cdot 8H_2O$ was the only salt obtained, boric acid crystallizing out with it if an excess was present.

A solution of the 1:5:8 compound, when boiled, loses ammonia, even when boric acid is added. It is possible, though, that with the proper quantity of boric acid added, an equilibrium can be reached, so that a solution of the 1:5:8 compound can be boiled without losing ammonia. Out of such a boiling solution, it is possible that the lower hydrate, namely the 1:5:5 compound, might crystallize. Time was not available for studying such possibilities.

In the analysis of ammonioborite, the sample was dissolved in cold water, solution being complete on standing over night. The cold water solution was titrated with $\frac{N}{10}$ HCl for the ammonia, using methyl red as indicator, an excess of $\frac{N}{10}$ NaOH solution then added, and the solution boiled for 20 minutes with a return condenser, open at the top. The boiling was continued for 5 minutes after the escaping steam no longer turned red litmus paper blue, due to the escaping ammonia. The excess alkali was then titrated to neutrality with methyl red as indicator and the freed boric acid then titrated with $\frac{N}{10}$ NaOH, using phenolphthalein and mannite.

A check on the titration method for alkali and for boric acid was made on recrystallized borax crystals, without the boiling with caustic soda. The analytical results obtained were in good agreement with the calculated values.

Table 4. Titration Method Checked by Analysis of Borax Crystals

	Found		Calculated
Na_2O	16.10	16.07	16.26
B_2O_3	36.58	36.71	36.52
H_2O (by diff.)	47.32	47.22	47.22
	100.00	100.00	100.00

As all the sassolite could be completely dissolved out of the mixture of sassolite and ammonioborite with cold water in ten minutes or so, a small quantity of pure ammonioborite for analysis was secured in this way. Only ninety-three milligrams of the pure mineral were so obtained and the following analysis (Table 5) made on this small quantity. For the analysis of the mixtures of the two minerals (Table 6) and for the other analyses given in this paper, 0.2 gram samples were used. The values obtained are given to two decimals simply for the sake of uniformity, though it is well realized that even the first decimal has little claim to accuracy.

TABLE 5. ANALYSIS OF PURE AMMONIOBORITE, FREE FROM SASSOLITE

Analysis		Ratios	
$(NH_4)_2O$	9.78	0.188 or 1.00	0.96 or 1×0.96 or 1
B_2O_3	74.18	1.066 or 5.67	5.47 or 5×1.09 or 5
H_2O (by diff.)	16.04	0.891 or 4.74	4.57 or 5×0.91 or 5
	100.00		

The water in this sample was necessarily determined by difference and consequently any error in the B_2O_3 determination will affect that of H_2O. The ratio of $(NH_4)_2O:B_2O_3:H_2O$, taking ammonia as unity, is, 1:00:5.67:4.74. If the B_2O_3 determination is a little high, as seems probable from the ratios, then that of water would be correspondingly low, so that the correct ratio would seem to be 1:5:5, giving the formula of amonioborite as $(NH_4)_2O \cdot 5B_2O_3 \cdot 5H_2O$.

Before the above analysis of ammonioborite free from sassolite was made, the natural mixture of the two minerals had been analyzed. In these analyses, the boric acid was titrated directly after the ammonia had been titrated with HCl, without realizing that the ammonia present (as ammonium chloride) would consume some NaOH, due to the reaction $(NH_4)Cl + NaOH = NaCl + (NH_4)OH$.

Some comparative tests were therefore made on the 1:5:8 artificial salt, of which abundant material was available, to see how far the presence of the ammonium salt would influence the determination of B_2O_3. The percentage of B_2O_3 determined in the 1:5:8 salt, without removing ammonium, is 66.49 (Av. of 66.88, 66.82, 66.00, 66.27). The percentage of B_2O_3, first removing ammonium by boiling with NaOH solution, was determined to be 64.48 (Av. of 64.33, 64.63). The B_2O_3 determination, without removing ammonium, is therefore about two percent too high. If the corresponding correction be applied to the determination of B_2O_3 in the ammonioborite-sassolite mixture, its analysis is as follows:

TABLE 6. ANALYSIS OF AMMONIOBORITE-SASSOLITE MIXTURE

	Analysis	Average	Ratio
$(NH_4)_2O$	5.71– 6.00	5.86	0.1127 or 1.00
B_2O_3	64.10–64.31	64.21	0.9226 or 8.19
H_2O (by diff.)	....	29.93	1.6628 or 14.75
		100.00	

In interpreting these ratios, that for $(NH_4)_2O$ is reduced to unity and the proper proportion of B_2O_3 and H_2O (1:3) deducted, to allow for the admixed sassolite.

TABLE 7. RATIOS OF ANALYSIS OF AMMONIOBORITE-SASSOLITE MIXTURE, DEDUCTING SASSOLITE

		Sassolite deducted	Ratios of pure Ammonioborite
$(NH_4)_2O$	1.00	....	1.00
B_2O_3	8.19	3.19	5.00
H_2O	14.75	9.57	5.18

By arbitrarily deducting enough B_2O_3 from the ratios of the mixture to yield a 5:1 ratio of $B_2O_3:(NH_4)_2O$, the ratio of the remaining water to $(NH_4)_2O$ is also 5:1, yielding the same ratio for the pure mineral as previously obtained, namely $(NH_4)_2O \cdot 5B_2O_3 \cdot 5H_2O$. According to these ratios, the mixture analyzed consisted of 57 per cent of ammonioborite. As ammonioborite theoretically contains 10.61 per cent $(NH_4)_2O$, the determination of 5.86 per cent $(NH_4)_2O$ shows that 55 percent of ammonioborite was present in the mixture—a close agreement.

X-RAY EXAMINATION

On the assumption that a study of the structures of these minerals by X-ray methods might contribute further evidence as to the difference between larderellite and ammonioborite, Dr. E. Posnjak of the Geophysical Laboratory kindly took photographs of the X-ray spectra of both these minerals, which are reproduced in Fig. 2. They show a distinct difference in the structure of the two minerals.

The sassolite present in the samples was dissolved out with cold water, and microscopic examination of the remaining powder showed that both were pure. The larderellite (L in Fig. 2) was furnished by Prof. E. S. Larsen from the Harvard Collection. The ammonioborite (A in Fig. 2) is from the sample wrongly labelled boussingaultite in the Roebling Collection (now in U. S. Nat. Mus. Cat. No. R6167), whose optical properties were described by Larsen under Boussingaultite No. 2 and reproduced in column 4 of Table 1.

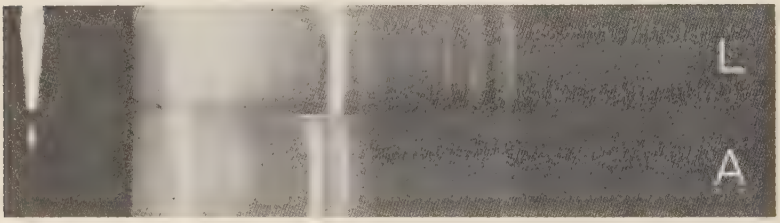

Fig. 2. *X*-ray spectra of larderellite (L) and ammonioborite (A). Taken by Dr. E. Posnjak of the Carnegie Geophysical Laboratory.

The 1:5:8 Artificial Salt

The well known salt $(NH_4)_2O \cdot 5B_2O_3 \cdot 8H_2O$, readily crystallizes out of a cold water solution in orthorhombic crystals, commonly forming twins and trillings. A quantity of this salt was prepared in order to have abundant material of an ammonium borate available for testing the chemical methods of analysis. It was found experimentally that a mixture of 40 grams boric acid, 35 c.c. strong ammonia, and 800 c.c. water, left to crystallize at room temperature, yielded a crop of crystals of the 1:5:8 compound, with very little free boric acid. Smaller quantities of ammonia always yielded an abundance of crystals of boric acid as well as the 1:5:8 salt.

The optical properties of the 1:5:8 salt are as follows, the data of the first two columns being taken from the literature. The results given by d'Achiardi are only approximate, the determination of β being considerably in error.

Table 8. Optical Properties of the Artificial Salt, $(NH_4)_2O\cdot 5B_2O_3\cdot 8H_2O$

	Bolland[a]	d'Achiardi[b]	Schaller	Ross
α	1.44 approx.	<1.471	1.425	1.426
β	.....	1.471	1.430	1.429
γ	1.485 approx.	1.498	1.488	1.486
Sign	+	.....	+	+
2V	46½° (red)	.....	.....	35°
Dispersion	.....	.....	.....	$r<v$

[a] Taken from Winchell, A. N., The optic and microscopic characters of artificial minerals: *Univ. Wisconsin Studies*, No. **4**, 1927, p. 56.

[b] Taken from Abstract (*Mineral. Abstracts*, vol. 5, p. 146, 1932) of d'Achiardi, G., Considerazioni e ricerche sulla larderellite, etc. *Periodico di Mineralogia*, vol. 3, (No. 1), pp. 1–9, 1932.

The analysis of the 1:5:8 salt yielded the following values (Table 9), the solution of the salt being boiled with an excess of NaOH solution to remove ammonia, before titration of the boric acid.

Table 9. Analysis of 1:5:8 Salt

	1	2	3	4	Average	Ratios
$(NH_4)_2O$	8.79	8.60	8.69	8.60	8.67	0.1667 or 0.90 or 1
B_2O_3[a]	64.33	64.63	....	....	64.48	0.9264 or 5.02 or 5
H_2O by diff.	.....	.....	....	....	26.85	1.4917 or 8.08 or 8
					100.00	

[a] Determination of B_2O_3 immediately after the ammonia titration with HCl, without boiling with NaOH solution to remove the ammonia, gave higher results, namely, 66.88, 66.82, 66.00, 66.27.

The ratios obtained are: 0.90:5.02:8.08; close to 1:5:8.

Determinations of loss upon ignition leaving only B_2O_3 behind, both the ammonia and the water escaping, show that a little B_2O_3 also escapes under these conditions (Table 10). For the ammonium borates, the residue after simple ignition does not yield accurate values for B_2O_3. Ignition with lime would probably retain all the B_2O_3.

TABLE 10. DETERMINATION OF B_2O_3 AS RESIDUE ON IGNITION, IN AMMONIUM BORATES, SHOWING TOO LOW A RESULT

	B_2O_3, as residue on ignition	B_2O_3, by titration
Mixture of ammonioborite and sassolite	62.30	64.10, 64.31
1:5:8 salt	62.72, 62.94	64.48
Boric acid	53.65	55.64, 55.83

A CHEMICAL AND OPTICAL STUDY OF PIEDMONTITE FROM SHADOW LAKE, MADERA COUNTY, CALIFORNIA

Allan M. Short, *Cornell University.*

Introduction

The purpose of this paper is to present some chemical and optical data on piedmontite recently collected near Shadow Lake, Madera County, California, and to discuss these in relation to the properties recorded from other occurrences.

Abundant material from the Shadow Lake area, collected by Dr. E. B. Mayo, and specimens in the Cornell Mineralogy Collection from Shikoku, Japan; South Mountain, Pennsylvania; and Saint Marcel, Italy, were generously furnished for this study.

Nature of the Material

The specimens from the Californian occurrence, containing well crystallized piedmontite were taken from a shear zone in schistose volcanic rocks about three hundred yards east of the outlet of Shadow Lake.

Since this zone served as a line of weakness along which mineralizing solutions could rise, the materials in it differ from those of the adjacent, previously described country rock (16),* in being more coarsely crystalline and containing a greater abundance of minerals that might have been formed from introduced substances (Fig. 1). The usual mineral association is piedmontite, tremolite and vein quartz, which were deposited in the order given. In addition some cavities in the rock are lined with small, orange-colored crystals of a garnet that gives the usual bead test for manganese.

The microscopic study has confirmed the order of deposition determined in the hand specimen. In thin section tremolite, itself enclosed in later quartz, can be seen replacing piedmontite. Near the replacement boundaries, the tremolite was darkened by minute inclusions of manganese oxide, doubtless derived from the epidote mineral. Sections parallel and perpendicular to the rock cleavage show that the majority of the piedmontite crystals have their *a* and *b* axes in the plane of schistosity.

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* Numbers in parentheses refer to the bibliography at the end of this paper.

CHEMICAL STUDY

As a preliminary to the complete quantitative analysis of the piedmontite, a spectroscopic comparison was made with material from other occurrences. The spectrograms obtained (Fig. 2), show the compositions to be almost identical. In all, the essential elements, silicon, aluminium, calcium, manganese and iron, together with some magnesium and traces of titanium, cerium, copper and lead were present; the last three being highest in the South Mountain sample, in agreement with the original analysis (8).

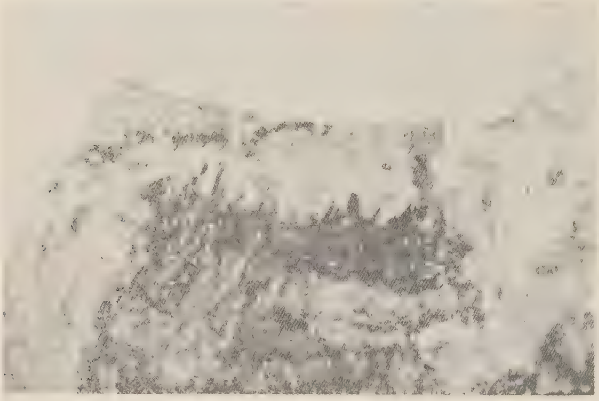

FIG. 1. Specimen ($\frac{3}{4}$X) from the shear zone of Shadow Lake, Madera County, California. Dark blades and needles of piedmontite, embedded in quartz and associated with white, fibrous tremolite.

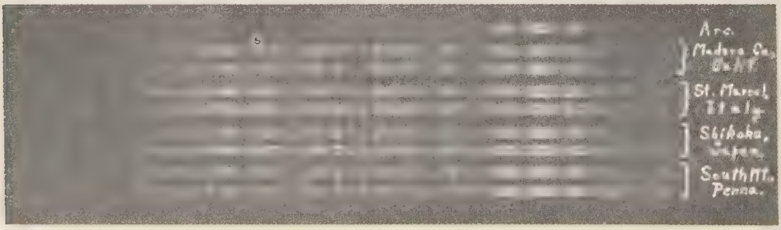

FIG. 2. Spectroscopic Comparison of Piedmontite from Four Occurrences.

In the sample for quantitative analysis and specific gravity determination, it was impossible to eliminate quartz as an impurity, but garnet and tremolite were easily avoided, as they were more or less localized. The sample was prepared, first by crushing and separating in bromoform to remove most of the quartz, then in Klein's solution (Sp. Gr. 3.33), and a final sorting under the binocular.

The specific gravity of this selected product, as obtained by the pycnometer method, was 3.44 at 22°C. or (D_4^{22} 3.43).

To compute the quartz impurity still in the piedmontite, a few pure, well crystallized fragments were selected and run for silica alone, which was found to be 35.26%. The silica in the complete analysis was then corrected to 35.26% and the whole analysis recalculated.

The specific gravity of the pure piedmontite was calculated from a sample (Sp. Gr. = D_4^{22} 3.43) having a quartz impurity (Sp. Gr. 2.654) of 2.79%. The true specific gravity was therefore (D_4^{22} 3.46).

Analysis of Piedmontite from Shadow Lake, Madera County, California

T. Kameda, Analyst

	Original	Recalculated
SiO_2	38.05%	35.26%
Al_2O_3	22.49	23.50
Fe_2O_3	4.45	4.65
MgO	0.20	0.21
CaO	21.75	22.73
H_2O	1.31	1.37
TiO_2	0.11	0.12
Mn_2O_3	11.61	12.13
Total	99.97	99.97

This analysis shows no MnO and the analyst states that if any is present, it is only a trace.

The published analyses of piedmontite are represented graphically (Fig. 3) in order of increasing Mn_2O_3 and some interesting, if not accurate, conclusions can be drawn. With the increase of Mn_2O_3 there is also an increase of MnO, in those analyses reporting this oxide, and a ratio of $Mn_2O_3:MnO=4:1$ is almost constant. The Saint Marcel mineral, analyzed by Hartwell, and that from California report no MnO but show a slight rise in the Mn_2O_3 curve, which doubtless indicates that the lower oxide was really present but has been included as manganic oxide. With increase of Mn_2O_3 there is a general decline of Al_2O_3, showing a replacement of Al_2O_3 by Mn_2O_3. Also there is a pronounced reciprocal relation between Fe_2O_3 and Al_2O_3. No FeO was reported in any of the analyses. The silica, as expected, varies between well defined limits, 35% to 38.5%. The CaO varies within a range of 5%, except in the analysis of the Saint Marcel piedmontite by Soboero. The relations between the amounts of CaO and MnO are not clear, although one would expect MnO and MgO to replace CaO. However, this series of analyses emphasizes the association of the R_2O_3 oxides and shows a possible relation between Mn_2O_3 and MnO.

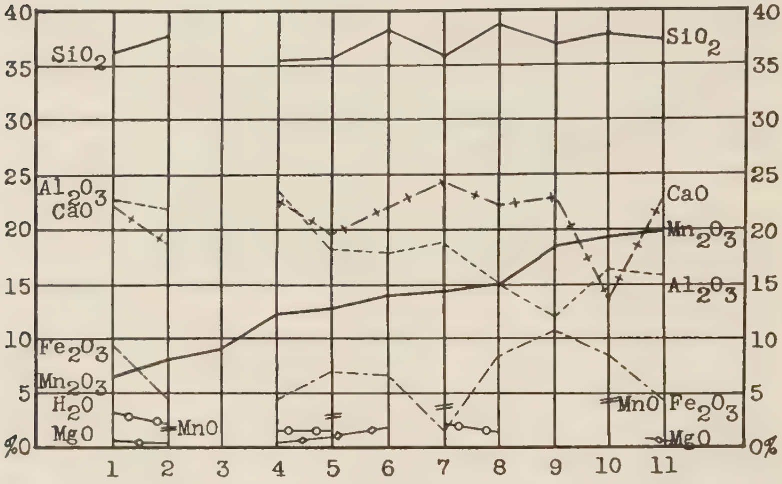

FIG. 3. Variations in the Composition of Piedmontite.

1. Island of Shikoku, Japan. (12)
2. South Mountain, Pennsylvania. (19)
3. Sulphur Springs Valley, Arizona. (15)
4. Madera County, California.
5. Kajlidongri, Jhabua State, Central India. (10)
6. Saint Marcel, Italy. Hartwell analyst. (9)
7. Saint Marcel, Italy. Laspeyres analyst. (13)
8. Saint Marcel, Italy. Rammelsberg analyst. (18)
9. Saint Marcel, Italy. Geffken analyst. (9)
10. Saint Marcel, Italy. Soboero analyst. (9)
11. Saint Marcel, Italy. Deville analyst. (9)

In general the above relationships support the accepted formula for piedmontite, but since the sesquioxides of aluminium, iron and manganese appear to mutually replace one another, and since MnO and small amounts of MgO are present, probably replacing

CaO, it appears that the formula, H (Ca, Mn, Mg)$_2$ (Al, Mn, Fe)$_3$Si$_3$O$_{13}$, expresses these relations more accurately.

OPTICAL STUDY

The optical properties of analyzed piedmontite, as recorded in the literature, are very incomplete, and evidently have not been studied as fully as have the chemical properties. Its pleochroism, which is most diagnostic, has been reported for all occurrences and evidently increases in intensity with the increase of manganic oxide (13, 19). In general the pleochroism for the various optical directions is (6, 7, 15, 19, 20):

X = shades of lemon yellow to orange and brownish orange.
Y = red to reddish violet and amethystine.
Z = light rose to carmine and blood red.

The Madera County piedmontite has the following pleochroism (16):

X = lemon yellow to orange.
Y = amethyst to amethystine red.
Z = carmine.

The indices of refraction were determined by immersion in liquids made up of solutions of AsBr$_3$ and AsS in methylene iodide (2). It was found that all the crystals and fragments did not have the same indices in corresponding directions and that they differed as much as ±.005, although there was no visible difference in the color or pleochroism. Similar variations have been observed in epidote from Telemarken, Norway (1). For this reason the means of the values obtained by this method were chosen as representative: $N_g = 1.7985$, $N_m = 1.7649$, $N_p = 1.7385$.

The optic axial angle $2V$ as calculated (11) from the indices was 76° 22′ and as measured on the universal stage varied from 64° to 75°.

The recorded numerical optical characteristics (12, 13, 14, 15) and data on specific gravity (18), although meagre, are shown graphically in order of increasing Mn$_2$O$_3$ content (Fig. 4). The lowest value shown for $2V$ (56°) was obtained from material representing the South Mountain occurrence (14), but it is not certain that this material had the composition indicated by Williams' analysis (19). This value however, fits the general trend of the optic axial angle curve very well.

The varying proportions of Mn_2O_3 and Fe_2O_3 produce interesting effects on the optical properties. When these two substances are present in approximately equal quantities, the resulting mineral is optically positive, and has $2V$ between 50° and 60°. The South Mountain mineral approaches this composition and has an optic axial angle of 56°. If the manganese is in excess, the optic axial angle increases, as in the piedmontite from Saint Marcel, analyzed by Laspeyres, in which Fe_2O_3 is to Mn_2O_3 as one to ten, and the optic angle is 82° to 90°. From this it is quite conclusive that a piedmontite without iron should be optically negative and have $2V$ close to 90°.

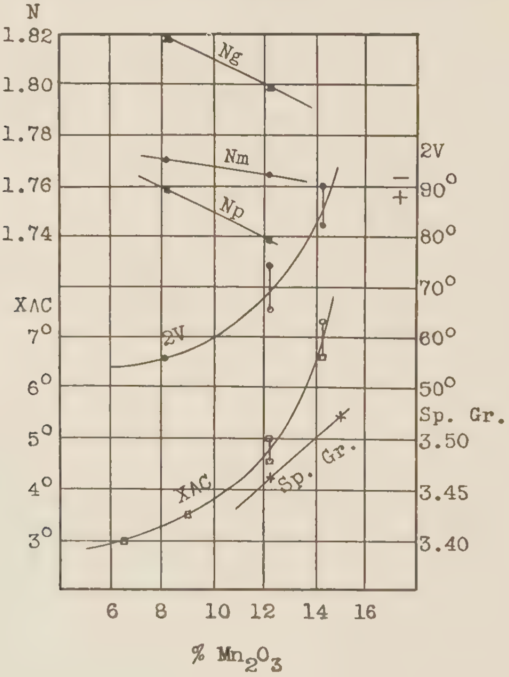

FIG. 4. Relation of Optical Properties and Specific Gravity to Mn_2O_3 Content of Piedmontite.

As Mn_2O_3 in piedmontite decreases in proportion to Fe_2O_3, as in withamite (4), it is highly probable that the $2V$ curve would rise sharply, becoming negative at about two or three percent Mn_2O_3 and with decreasing optic angle pass into ordinary epidote.

The increase of Mn_2O_3 also increases $X \wedge c$ and the specific gravity, and decreases the indices of refraction. From data recorded by Larsen (14) and from Andersen's conclusions (1), it is very probable that the N_g and N_p curves converge with increase of Mn_2O_3 but not enough data are available to justify a definite statement.

In reviewing the literature it was found that little optical research has been done on material represented by chemical analyses, and correlation between the various data can not be made with accuracy. Since this manganese-bearing epidote, although rare, is becoming better known as a rock-forming mineral, further optical study of analyzed material would seem desirable. The possible relations indicated in this paper require confirmation and merit considerable further investigation.

Acknowledgments

The writer wishes to express his thanks to Dr. E. B. Mayo who furnished the material and incentive that made this study possible and for his helpful criticism of the manuscript; and also to Mr. K. W. Sherk of the Cornell Chemistry Department for the spectroscopic analyses.

References

1. Andersen, O., On Epidote and Other Minerals from Pegmatite Veins in Granulite at Notodden, Telemarken, Norway: *Archiv. f. Mathematik og Naturvidenskab, Bull.* **31**, pp. 27, 34 and 36.
2. Borgström, L. H., Ein Beitrag zur Entwicklung der Immersionsmethode: *Comm. Géol. de Finlande, Bull.* **87**, p. 58, 1929.
3. Cordier, M., Analyse du Minéral connu sous le nom de Mine de Manganèse violet du Piédmont: *Jour. de Min.*, vol. **13**, p. 135, 1893.
4. Dana, E. S., Dana's System of Mineralogy. Sixth edition, p. 522, **1892**.
5. Des Cloizeaux, Manuel de Minéralogie, vol. **1**, p. 254, 1862.
6. Fermor, L. L., The Manganese Deposits of India: Mineralogy, *Mem. Geol Surv. of India*, vol. **37**, pp. 187–191, 1909.
7. Hall, A. L., The Contact Belt of the Older Granite in the Barberton District and Northern Swaziland: *Trans. Geol. Surv. S. Africa*, vol. **20**, p. 15, 1917.
8. Hillebrand, W. F., Analyses of Rocks and Minerals from the Laboratory of the U. S. Geol. Survey: *U. S. Geol. Surv., Bull.* **419**, p. 272, 1910.
9. Hintze, C., Handbuch der Mineralogie, vol. **2**, p. 256, 1897.
10. Jakob, J., Analysis of Piedmontite from Kajlidongri Jhabua State, Central India: *Records of Geol. Surv. of India*, vol. **LXIII**, Part 1, p. 26, 1932.
11. Johannson, A., Manual of Petrographic Methods, Second edition, p. 103, **1918**.

12. Koto, B., Some Occurrences of Piedmontite in Japan: *Jour. Coll. Sci., Imp. Univ. Tokyo*, vol. **1**, Part 3, pp. 303–312, 1887.

——— On Some Occurrences of Piedmontite Schist in Japan: *Quart. Jour. Geol. Soc.*, vol. **43**, pp. 474–480, 1887.

13. Laspeyres, Die chemischen Untersuchungen der Epidotgruppe: *Zeit. für Kryst.*, vol. **3**, p. 524, 1879.

——— Die krystallographischen und optichen Eigenschaften des Manganepidot (Piedmontit): *Zeit. für Kryst.*, vol. **4**, p. 435, 1880.

14. Larsen, E. S., The Microscopic Determination of the Nonopaque Minerals· *U. S. Geol. Surv., Bull.* **679**, pp. 120, 228 and 230, 1921.

15. Lausen, C., Piedmontite from Sulphur Springs Valley, Arizona: *Amer. Mineral.*, vol. **12**, pp. 283–287, 1927.

16. Mayo, E. B., Two New Occurrences of Piedmontite in California: *Amer. Mineral.*, vol. **17**, pp. 238–248, 1932.

17. Napione, C., Analyse de la Mine de Manganèse Rouge du Piédmont: *Mem. de l'Academie Royale des Sciences*, p. 303, **1788–1789**.

18. Rammelsberg, C., Handbuch der Mineralchemie, p. 595, **1875**.

19. Williams, G. H., Piedmontite and Scheelite from the Ancient Rhyolite of South Mountain, Pennsylvania: *Amer. Jour. Sci.*, vol. **46**, pp. 50–57, 1893.

20. Zeigler, V., Minerals of the Black Hills: *South Dakota School of Mines, Bull.* **10**, p. 164, 1914.

Eitel, W., Die Grenzen der Mischkristallbildung in den Mineralien der Epidotgruppe. *Neues Jahrb.*, vol. **42**, pp. 173–271, 1918.

Hall, A. L., *Minutes of Proc. Geol. Soc. S. Africa*, p. xlii, **1917**.

Lacroix, A., Minéralogie de La France et Ses Colonies, vol. **1**, p. 152, 1893.

NOTES AND NEWS

NOTES ON MINERAL LOCALITIES IN MAINE

Lloyd W. Fisher, *Bates College.*

Chrysoberyl

Many museums in the United States have crystals of chrysoberyl that were found in the Ragged Jack Mountain locality in the town of Hartford, near the Peru line. Dana's Textbook of Mineralogy, 3rd ed., p. 424, lists chrysoberyl in Maine from Norway, where it is associated with garnet in granite; from Stoneham, with fibrolite; and from Buckfield, Greenwood and Topsham. No mention is made of the Ragged Jack Locality although Palache described the area in this journal.[1] Mr. Dudley, of Buckfield, is given the credit of being one of the original discoverers of the ledge. The area was visited July 1933 by the writer in company with T. Wilson Bonney, discoverer of the ledge,[2] and others. During this visit numerous small and fairly clear pieces of chrysoberyl were found.

Ragged Jack Mountain is composed chiefly of gneissoid biotite granite. Its western cliff, easily noted on the Buckfield (Maine) quadrangle, faces Black Mountain, the outstanding topographic feature in the immediate vicinity. Many good specimens of chrysoberyl have been found in the talus material at the base of the sheer cliff. The chrysoberyl-pegmatite is exposed at the base in a vein about four feet wide. The vein continues in a diagonal line up the full height of the cliff, about 125 feet. Attempts have been made during the past year, 1933, to work the pegmatite. A shaky ladder has been placed from the talus slope to the cliff face.

The pegmatite near the base of the cliff shows a segregation of milky quartz in which there are some large schorl crystals and feldspar, the latter being abundant on one side of the vein. Quartz is the chief constituent of the lower part of the exposed vein. A rich development of muscovite mica in books reaching ½ inch in thickness and intimately associated with biotite occurs on the lower left side of the vein. The biotite forms large patches locally in the dike. The muscovite is characterized by a peculiar curved cleavage and, in mass, resembles amber mica. Almandite garnets in the feldspar are three-quarters of an inch in size and in well developed trapezohedrons. Quartz occurs in several varieties—milky, smoky, amethystine and iron stained—but the glassy vein quartz is most abundant.

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[1] Palache, Charles, Chrysoberyl pegmatite of Hartford: *Am. Mineral.*, **9**, pp. 217–221, 1924.

[2] Communication from S. C. Simms, Field Mus., Chicago:—"Three specimens of chrysoberyl from Ragged Jack Mountain were sold the Field Museum in 1908 by T. W. Bonney, of Buckfield, who described the location about 15 miles northeast of Mount Mica near the townline of Hartford and Peru."

Chrysoberyl is more abundantly associated with quartz than with feldspar. The largest piece found measures $2\frac{1}{8}''$ by $2\frac{3}{4}''$ by $\frac{3}{16}''$. Most of the pieces of chrysoberyl are badly shattered. One piece in quartz is bordered by a thin strip of schorl and is coated with a secondary micaceous product. Most of the chrysoberyl is not more than $\frac{1}{8}''$ thick.[3] It breaks from the enclosing quartz or feldspar with marked facility. The specimens are wine yellow, although some with a definite greenish cast were seen. Twinned and simple crystals of both colors were found. The twinning striations are impressed on the feldspars and are seen where the chrysoberyl crystals have been broken out.

Tourmaline, schorl variety, is also quite abundant. One small partial crystal with a perfect rhombohedral-like termination measured $1\frac{1}{8}''$ in diameter and $1''$ in length. Several broken prisms of tourmaline are rehealed by quartz. Portions of milky quartz carry the impressed striations of the schorl.

The writer is not aware that apatite has ever been listed from this locality, although it is abundant in nearby quarries. A fairly well developed apatite crystal was found. It measures about $\frac{3}{4}''$ in length and the side of the prism measures $\frac{3}{8}''$ at the base. It is probably later in crystallization than the feldspar with which it is associated. One prism face of the apatite has entered the cleavages of the feldspar. A portion of the crystal is broken and rehealed by quartz. A smaller, nearly perfect hexagonal outlined crystal was found in the same specimen entirely enclosed by quartz.

[3] The largest specimen now in Mr. Bonney's collection is 1/8″ thick, and 2″ by $1\frac{1}{2}''$. Some of it is of gem quality.

GRAPHITE

The writer is preparing a paper* on an occurrence of graphite in a pegmatite near Lewiston, Maine, and while studying the litera-

* Article will appear in a future issue of the Journal.

ture on Maine mineral localities, encountered the following statement:[1]

> "About twelve years ago quite an excitement was caused by developments in the vicinity of Oak Hill in Wales. Thomas Barr's farm, at Ray's Corners, had rock in 1876 bearing $25 of pure silver to the ton. Plumbago had earlier been mined there, and sulphuret of silver was said to exist in the same mine and its vicinity."

The area referred to is located in the Lewiston quadrangle, central rectangle, on the western slope of a low hill bordering Sabattus Lake on the west. A road leads northwesterly from the village of Sabattus and at a point one and two-tenths miles from the village an old logging road enters the woods to the east. The old mine prospect is located on the continuation of this road near the top of the hill.

The country rock of the area is quartz-mica schist dipping at a steep angle to the west. The schists carry considerable graphite. They are intruded by a fairly coarse grained granite pegmatite which contains black tourmaline. In none of the rocks examined were any traces of silver ore found.

The mine was worked by trenching. A long trench cut down the hillside slope is now overgrown with brush but it can be traced for more than 100 feet. Several smaller trenches branch off from this main one. Large piles of rocks on the dump indicate past mining activity. None of the rocks on the dump showed any black minerals except graphite and schorl.

A resident in the immediate section for over 35 years was questioned. He (a Mr. Wakeley) stated that the mine had not been worked during his residence there. The materials obtained from the mine during its period of operation were sold to a firm that made shoe and stove polish.

Gold was reported from another locality at the forks of the road —Ray's Corners—beyond the logging road leading to the old silver prospect. Quartz veins, pegmatite intrusions, materials in the walls and boulders in the fields were examined but no gold was found. Old residents in the area knew nothing about the "gold" occurrence.

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[1] Merrill, G. D., History of Androscoggin County, Maine, p. 31, W. A. Fergusson and Co., *Boston*, **1891**.

DIRECTORY OF AMERICAN AND CANADIAN MINERAL COLLECTIONS

SAMUEL G. GORDON, *Academy of Natural Sciences of Philadelphia*

(*Continued from page 468*)

UTAH

PROVO	BRINGHAM YOUNG UNIVERSITY MUSEUM, Deseret Museum, Collections, in Part.
SALT LAKE CITY	UNIVERSITY OF UTAH. An extensive collection.
	WESTMINSTER COLLEGE. A general collection including that of Robert Forrester (in part), rich in Utah minerals. Open to visitors at all times.
TORRY	JUNE COVINGTON.

VERMONT

BURLINGTON	UNIVERSITY OF VERMONT A general collection of about 1000 specimens. E. C. Jacobs, Custodian. May be seen daily.
CUTTINGSVILLE	JULIUS W. EGGLESTON, 20 Copperas Hill. About 1000 general and local specimens.
	H. W. RIDLON.
MIDDLEBURY	MIDDLEBURY COLLEGE
MONTPELIER	STATE BUILDING. Vermont minerals and rocks.
ST. JOHNSBURY	FAIRBANKS MUSEUM OF NATURAL SCIENCE. Mabel A. Shields, Curator. A general and local collection of 1500 specimens. Open weekdays 9 A.M. to 5 P.M., and on Sundays from 2:30 P.M. to 5 P.M.
SOUTH LONDONDERRY	CHARLES COLBURN.
WESTFIELD	HITCHCOCK MEMORIAL MUSEUM

VIRGINIA

BLACKSBURG	VIRGINIA POLYTECHNIC INSTITUTE. A general collection of 2000 specimens (including the private cabinet of Professor R. J. Holden) is in the Department of Geology in Davidson Hall. It may be seen from 8 A.M. to 5 P.M. during the school term.

Emory Emory and Henry College.

Lexington Virginia Military Institute.

Washington and Lee University.

Richmond State Museum, Capital Square.

Minerals illustrating the resources of Virginia. J. G. Blount, Custodian. Open 8:30 A.M. to 5 P.M. on weekdays, 8:30 A.M. to 5:30 P.M. on Saturdays and Holidays, closed Sundays.

Roanoke Virginia Museum of Natural History

Salem Roanoke College.

University (Charlottesville) University of Virginia, Brook's Museum.

A general collection of 2000 specimens. Open daily except Sunday, 8:30 A.M. to 5 P.M.

WASHINGTON

Burton Vashon College.

Hoquiam W. H. Matchett, 411 M Street.

Lapidary. Collection of minerals and gems.

Port Angeles Klahhane City Museum.

Pullman State College of Washington, Science Hall.

A general teaching collection of 1500 specimens. Custodian, Malvin G. Hoffman.

Seattle State Museum

Dr. Erna Gunther, Director. A general collection of 200 specimens. Open every day from 1 P.M. to 5 P.M.

University of Washington, State Museum.

The Baker Collection, and a rather complete collection of Washington minerals.

Spokane Public Museum, 2316 First Street.

C. O. Fernquist, Curator of Mineralogy.

Tacoma B. H. Bennetts, 1131 Market Street.

Collection of ores.

Terry Museum of Tacoma.

Washington State Historical Society.

Small general collection.

Walla Walla Whitman College, Whitman Museum.

H. S. Brode, Curator. About 1300 specimens are exhibited. These may be seen on request.

WEST VIRGINIA

Morgantown	West Virginia University, Chemistry Building.

A general collection of 2000 specimens. Open daily from 2 P.M. to 5 P.M. except Saturdays and Sundays. Dr. J. H. C. Martens, Custodian.

WISCONSIN

Appleton	Lawrence College, Science Hall.

A general and local collection. Dr. Rufus Mather Bagg, Custodian. May be seen Monday and Wednesday afternoons, or by appointment.

	Rufus Mather Bagg, 16 Brokaw Place.
Beloit	Beloit College, Science Building.

A general collection of 600 minerals. Open daily 8 A.M. to 12 M, and from 1 P.M. to 5 P. M. M. E. Wing, Curator.

Green Bay	Neville Public Museum.
Madison	University of Wisconsin, Department of Geology.

Teaching collections.

Milton	Milton College.
Milwaukee	Milwaukee-Downer College, Greene Memorial Museum.

Contains the Thomas A. Greene Collection. Carol Y. Mason, Curator. A general collection of 13,500 specimens may be seen by appointment.

	Milwaukee Public Museum.

Ira Edwards, Custodian. A general collection of 20,000 specimens, including the Charles Quarles Cabinet, rich in Wisconsin lead minerals and Lake Superior minerals. Synoptic collection of meteorites. Open November 1 to May 1, 9 A.M. to 9 P.M., Sundays, 1:30 P.M. to 9 P.M. May 1 to November 1, 9 A.M. to 5:30 P.M., Sundays 1:30 P.M. to 5 P.M.

New London	New London Public Museum.
Oshkosh	Oshkosh Public Museum.
Racine	Racine Memorial Museum.

Includes the Blake Collection of minerals.

Ripon	Ripon College, East Building.

A small general collection, which includes the Barber and Armstrong collections, and the New Orleans Collection from the New Orleans Exposition. J. F. Groves, Custodian.

St. Francis	Salzmann Museum.
Watertown	Northwestern College.

WYOMING

Cheyenne	C. S. Dietz, Carey Annex Building. Wyoming State Geological Department, 313 Capitol Building.

A state collection. John G. Marzel, Custodian. Open weekdays from 9 A.M. to 5 P.M.

Laramie	University of Wyoming.
Yellowstone Park	Yellowstone Museum.

CANADIAN COLLECTIONS

ALBERTA

Banff Rocky Mountains Park Museum.

BRITISH COLUMBIA

Britannia Beach	Frank Ebbutt.

A collection of 800 minerals and ores.

Vancouver	Art, Historical, and Scientific Association. Vancouver City Museum.

A collection of 500 specimens including the Dr. Roland Grant's Collection. T. P. O. Menzies, Curator.

Victoria	Mineral Museum, Bureau of Mines.

John D. Galloway (Provincial Mineralogist) Custodian. Principally an economic collection of British Columbia minerals and ores. Office hours: weekdays, 9 A.M. to 5 P.M. Saturdays 9 A.M. to 1 P.M.

MANITOBA

Winnipeg	University of Manitoba.

NEW BRUNSWICK

Chatham	Miramichi Natural History Association Museum.
Fredericton	Universtiy of New Brunswick.
Saint John	The New Brunswick Museum (Formerly The Natural History Society of New Brunswick).

Eight thousand specimens, including the original contents of Gesner's Museum of Natural History—that of the first government Geological Survey in Canada, and assembled by Dr. Abraham Gesner. Open daily from 10 A.M. to 5 P.M.

NEWFOUNDLAND

St. John's	Geological Survey of Newfoundland, Museum.

NOVA SCOTIA

Halifax Dalhousie College, Museum.
Provincial Museum of Nova Scotia.

Harry Piers, Curator. A collection of 6,952 specimens, mostly from Nova Scotia, including the Henry Howe Collection. Open weekdays 10 A.M. to 4 P.M., Saturdays from 10 A.M. to 1 P.M.

Truro County Academy, Museum.
Windsor King's College, Museum.
Wolfville Acadia University.

Small collection, chiefly Kings County minerals.

ONTARIO

Cobalt Arthur A. Cole (Temiskaming and Northern Ontario Railway office).

A collection of Northern Ontario minerals and ores.

Collingwood Huron Institute, Museum.
Guelph Ontario Agricultural College.

A general collection of 600 specimens.

Haileybury Bernard W. Hartley, Box 15.

A collection of 2500 minerals, ores, and gems.

Kingston Queen's University, Miller Hall.

A general, and Ontario collection of 35,000 minerals and ores. Open daily except Sundays.

Ottawa Geological Survey of Canada, Museum.
University of Ottawa.
Perth A. M. Campbell, Box 285.

A general collection, including part of the collection of Dr. James Wilson.

Perth Municipal Museum, Perth Public Library Building, opposite Town Hall.

A general collection, including part of the collection of Dr. James Wilson which had been housed in the Perth Collegiate Institute. A. M. Campbell, Curator.

Toronto Ontario Provincial Museum.
Royal Ontario Museum of Mineralogy, 100 Queen's Park.

Dr. T. L. Walker, Director. A large general collection, including the W. F. Ferrier collection, in part. Rich in Canadian minerals. Open weekdays from 10 A.M. to 5 P.M., Sundays from 2 P.M. to 5 P.M.

Victoria University.

QUEBEC

Lauzon	College St. Joseph de Lévis.
Longueuil	Longueuil College.
Montreal	Ecole Normal Ste. Croix.
	École Polytechnique, 1430 St. Denis Street.

A general and local collection of 5000 specimens. A Mailhiot, Custodian. May be seen upon request.

	McGill University, Peter Redpath Museum.

Contains the Walter F. Ferrier collection, in part, and the Holmes and Miller collections.

	Montreal College.

Possesses a collection made by Abbe Haüy.

	Natural History Society of Montreal.

Has a C. U. Shepard collection of 4000 specimens, presented by Dr. Holmes.

Quebec	Laval University.

A large collection of Canadian minerals, and a collection made by Abbe Haüy.

	Museum of Public Instruction.
Saint-Laurent	Collége Saint-Laurent.

A large mineral collection.

	Convent Des Soeurs de Saint-Croix.
Sherbrooke	St. Charles Seminary, Museum.

A small mineral collection.

Additions and Corrections to the Directory

Additions

CALIFORNIA	Sunnyvale: William B. Pitts, 530 Frances Street. Cut semi-precious and ornamental stones.
IOWA	Redfield: Mark C. Bandy.
MAINE	South Portland: Leonard H. Starbird.
MASSACHUSETTS	Cambridge: George H. Barton, 89 Trowbridge Street. Melrose: E. R. Chadburn, 394 Pleasant Street.
NEW HAMPSHIRE	Lebanon: Mrs. Frank C. Churchhill.
NEW YORK	Scarsdale: James G. Manchester. Local minerals.
PENNSYLVANIA	Allentown: Eugene W. Blank, 241 N. Ninth Street. Freeland: John J. Shrader, 184 Alvin Street.

CORRECTIONS

Page 316, Line 7: Read MOCALNO.
“ 320, “ 10: Delete comma after IRENEE.
“ 323, “ 20: Set line “CHILDREN’S MUSEUM. . . .” in.
“ 363, “ 30: Read HAMLIN.
“ 364, “ 31: “ BELLO.
“ 412, “ 16: “ F. R. Quinn.
“ 412, “ 19: “ Captain George Rowe.
“ 418, Last line “The collection is destined for the American Museum of Natural History.” Refers to the William Boyce Thompson Collection at Greystone (listed on page 415).
“ 461, Next to last line: Read 25 instead of 20.
“ 465, Line 2: Read 4217 Pine Street.
“ 467, Delete lines 23 and 24 under “Clarksville.”

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, June 1, 1933.

A stated meeting of the Society was called to order by President Trudell, with 48 members and 45 visitors present. The following were elected members: Messrs. Nicola d’Ascenzo, David Walker, and William Hutchinson. The following proposals for membership were referred to the executive council: Messrs. Clifton V. Mimms and Henry Moor.

Microscopic Mineralogy and Exhibition of Mounted Specimens, under the direction of Dr. L. C. Wills, was on the program for the evening. Twelve rotating tables equipped with microscopes, and in charge of an experienced operator, had been set up in the Academy’s lecture hall. Many unique and beautiful specimens were thus shown.

W. H. FLACK, *Secretary*

THE MINERALOGICAL SOCIETY OF AMERICA

The Fourteenth Annual Meeting of The Mineralogical Society of America will be held at the University of Chicago, Chicago, Illinois, on December 28–30, 1933, in conjunction with the Geological Society of America.

Headquarters and place of registration will be in the Reynolds Club, University of Chicago, 57th Street and University Avenue.

The first session of the Mineralogical Society will be held at 2 P.M. on Thursday December 28. It is planned to publish in the December issue of the Journal a *preliminary list* of titles of the papers to be presented before the Society at its annual meeting.

There are numerous hotels near the University and arrangements for the use of the University dormitories and International House have been made. Requests for hotel reservations should be sent directly to the hotels. Reservations for International House and Dormitories should be sent to Prof. R. T. Chamberlin, Rosenwald Hall, University of Chicago.

	With bath		Without bath	
	single	double	single	double
International House 59th and Dorchester			$2.00	
University of Chicago Dormitories			2.00	3.00
Shoreland Hotel Hyde Park, Chicago	$4.00	$5.50		
Hotel Windermere East Hyde Park	4.00	5.50		
Hotel Windermere West Hyde Park	3.00	4.50		
Gladstone Hotel 62nd and Kenwood	2.50	3.00	1.50	2.00

Arrangements are being made for reduced railroad rates on the certificate plan of a fare and one half for all members of the affiliated societies and their families. Be sure to obtain the identification certificate for each ticket at the time of purchase.

Albert B. Peck
Acting Secretary

Mineralogical Laboratory,
University of Michigan,
Ann Arbor, Michigan.

NOMINATIONS FOR OFFICERS OF THE MINERALOGICAL SOCIETY OF AMERICA FOR 1934

The Council has nominated the following for officers of The Mineralogical Society for the year 1934.

For President:
  John E. Wolff, Pasadena, California.

For Vice-President:
  W. A. Tarr, University of Missouri, Columbia, Missouri.

For Treasurer:
  Waldemar T. Schaller, U. S. Geological Survey, Washington, D.C.

For Secretary:
  Paul F. Kerr, Columbia University, New York City.

For Editor:
  Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.

For Councillor, 1934–1937:
  Edward P. Henderson, U. S. National Museum, Washington, D.C.

Albert B. Peck
Acting Secretary

NEW MINERAL NAMES

Girnarite

K. K. Mathier and A. G. Jhingran: A New Member of the Hastingsite Group of Amphiboles from Mount Girnár. *Quart. Jour. Geol. Min. Metal. Soc. India,* **3,** No. 3, 93–101, 1931.

Name: From the locality Mount Girnár, Kathiawar, India.

Chemical Properties: Analysis: SiO_2 34.67, 34.71; Al_2O_3 13.30, 13.21; Fe_2O_3 10.06, 10.23; FeO 14.77, 14.57; MgO 6.21, 6.22; CaO 10.58, 10.60; Na_2O 5.78, 5.89; K_2O 1.08, 1.05; MnO 0.27, 0.13; TiO_2 2.88, 2.90; P_2O_5 1.08, 1.08; ign. 0.03, 0.03; Sums 100.71, 100.62.

Crystallographical Properties: Monoclinic. Cleavage good at 123°; frequently twinned parallel to (100).

Physical and Optical Properties: Color brown, strongly pleochroic. X = deep brown, Y = straw yellow, Z = yellow. Biaxial, $2V = 76°$, $\alpha = 1.680$, $\beta = 1.694$, $\gamma = 1.704$. $Z \wedge c = 9°$ in the obtuse angle. Sp. Gr. = 3.42.

Occurrence: Found in nepheline syenite at Mount Girnár.

W. F. F.

Minyulite

E. S. Simpson and C. R. LeMesurier: Minyulite, a new phosphate mineral from Dandaragan, W. A. *Jour. Roy. Soc. Western Australia,* **19,** 13–16, 1932–33.

Name: From the locality Minyulo Well, near where the mineral was discovered.

Chemical Properties: A hydrous basic phosphate of potassium and aluminum, $2K(OH, F)\cdot 2Al_2O_3\cdot 2P_2O_5\cdot 7H_2O$. Analysis: K_2O 12.30, Na_2O 0.45, Al_2O_3 29.98, Fe_2O_3 tr., CaO, MgO nil, P_2O_5 35.58, F tr., H_2O $(-200°)$ 17.84 $(+200°)$ 2.79. Sum 98.94. Readily soluble in warm dilute NaOH and in hot concentrated HCl and slowly soluble in warm dilute HNO_3. Soluble in hot concentrated H_2SO_4 slightly etching a glass surface in contact with it.

On heating in a closed tube it decrepitates and yields much acid water which etches the glass, finally melting into an opaque white globule.

Crystallographical Properties: Orthorhombic.

Physical and Optical Properties: Color white, luster silky. Fragile. Hd. = 3.5. Sp. Gr. 2.45. Biaxial. $\alpha = 1.531$, $\beta = 1.534$, $\gamma = 1.538$. Extinction parallel, elongation negative.

Occurrence: Found in radiating groups filling minute veins or cavities in a highly phosphatic ironstone bed made up of limonite, quartz grains, dufrenite, nodular apatite and glauconite grains.

W. F. F.